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EFFECT OF SHADING ON THE PERFORMANCE ON SOLAR PHOTOVOLTAIC

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ABSTRACT

The output of the solar cell is a very significant parameter in the design of production of the photovoltaic one, although the electric output generated by a photovoltaic module or a solar cell can be decreased compared to the optimum conditions for production (maximum power point MPP). This article investigates the losses which occur in the performances of a photovoltaic cell, the main objective is to find the parameters of the nonlinear *I–V* equation by adjusting the curve at three points: voltage open circuit, maximum power point, and current short circuit. Especially when the level of the solar irradiation is not uniform. Then we studied experimental the shadow effect of a PV cell and also the influence of temperature, finally we show the importance of this point MPP in a photovoltaic module of monocrystallin type illumined according to the two faces (side and opposite the sun).

KEYWORDS: Silicon Mono-Crystalline, Solar Cells, Shadow Effect, Maximum Power Point, Fill Factor, Efficiency

INTRODUCTION

The world energy demand is steadily increasing. Fossil fuels and nuclear energy are at the moment the main energy sources for the world. All these resources are limited. The peak of depletion of mineral oil might be as soon as 2006 [1]. Therefore, renewable energy resources such as solar energy will play a significant role in the world energy in the upcoming future [2].

Solar energy is the sun's radiant energy where the radiate amount is enormous. Solar energy can be converted directly into electrical energy via solar cell and the phenomenon is commonly described as photovoltaic (PV) effect [3]. The conversion of solar energy to electrical energy is static, quite, free of moving object and does not have any negative impact to the environment.

Solar cells directly convert sunlight into electricity without polluting by-products and represent a promising, environmentally attractive technology to cover the world's future energy needs. Today, most terrestrial solar cells are made from silicon (Si). This has the advantage of using a raw material that is cheap, abundant and non-toxic, and there is the benefit of three decades of extensive experience in processing the material. The disadvantages of Si are lower theoretical efficiencies; compared to cells based on gallium arsenide, and the fact that long wavelength light is only weakly absorbed in Si, which requires relatively thick devices [4].

The present shadow study on the solar surface was made on a photovoltaic cell basic of a silicon monocrystalline. In this paper the measurement results of solar cells from different irradiance are presented. Then the shadow effect of cell has been investigated regarding their IV-characteristics to light intensities. The MPP caused by shading is the main subject of the present work. The paper presents a study on this problem, and on the techniques which can be used to mitigate the

performance decrease of the photovoltaic cell. Finally, the I-V curve of the cell is not rectangular but exponential, so that the maximum power output is further reduced by the fill factor.

THE PHOTOVOLTAIC EFFECT

A photovoltaic cell is a doped semiconductor so that an n-p-junction is obtained. This gives rise to an electric field inside the semiconductor. If a photon (a radiant energy quantum), hits an electron with high enough energy, it is torn off the atom and transported by the electric field to the other side of the junction, thus giving rise to a voltage across the junction. If an external load is connected between the n- and p, a DC-current will flow. The power from the photovoltaic cell depends on the light irradiation but also on the load and the temperature of the photovoltaic cell [5].

Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The monocrystalline and polycrystalline silicon cells are the only found at commercial scale at the present time.

The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited [6]. Charges are generated when the energy of the incident photon is sufficient to detach the covalent electrons of the semiconductor-this phenomenon depends on the semiconductor material and on the wavelength of the incident light. Basically, the PV phenomenon may be described as the absorption of solar radiation, the generation and transport of free carriers at the *p-n* junction, and the collection of these electric charges at the terminals of the PV device [7].

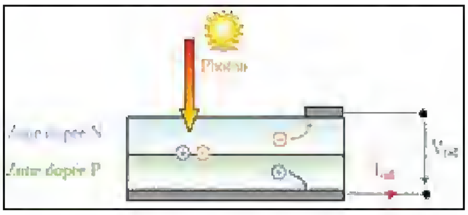

Figure 1: Physical Structure of a PV Cell

MATHEMATICAL MODELLING

A mathematical description of current - voltage terminal characteristics for PV cells is available in literature. The single exponential equation which models a PV cell is derived from the physics of the PN junction and a double exponential equation may be used for the polycrystalline silicon cell which gives a better precision [8].

The electrical equivalent circuit of a solar cell is commonly represented by two diodes model [9].

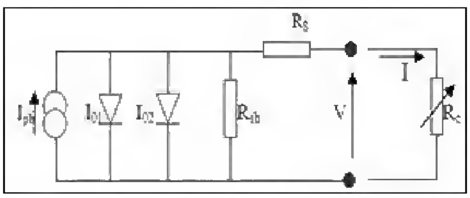

Figure 2: Electrical Equivalent of Solar Cell (Two-Diode Model)

The characteristic current voltage of a solar cell is described by the following implicit equation [9]:

$$I = I_{ph} - \frac{V + R_s I}{R_{sh}} - I_{01}\left[\exp\left(\frac{q(V + R_s I)}{KT}\right) - 1\right] - I_{02}\left[\exp\left(\frac{q(V + R_s I)}{nKT}\right) - 1\right]$$

Where I_{ph} is the current generated by the incident light (it is directly proportional to the Sun irradiation), I_{01} the

current one of diffusion, I_{02} the current due to the recombination by center of traps in the zone of space charge. q is the electron charge (1.602×10^{-19} *C*), V is the voltage across the diode (*V*), K the Boltzmann's constant (1.381×10^{-23} *J/K*), T the junction temperature in *Kelvin (K)*. n an ideality factor of the diode, R_s is the series resistance of diode, R_{sh} the shunt resistance of diode.

The complete behaviour of PV cells are described by five model parameters (I_{ph}, n, I_s, R_s, R_{sh}) which is representative of the physical behaviour of PV cell/module. These five parameters of PV cell/module are in fact related to two environmental conditions of solar in solation and temperature.

EXPERIMENTAL RESULTS

In this work, the system of measurements is consists of a silicon solar cell of area (2,5×5)cm^2, a digital multi meters, a voltmeter , a halogen lamp of 100 W, An optical bench on which is placed the cell to study making it possible to vary flow ,and also a suitable load resistance. The results obtained by this experiment are given by following figures:

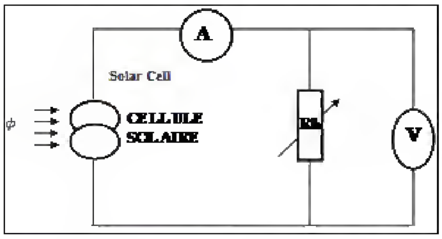

Figure 3: The Diagram Equivalent of the Solar Cell

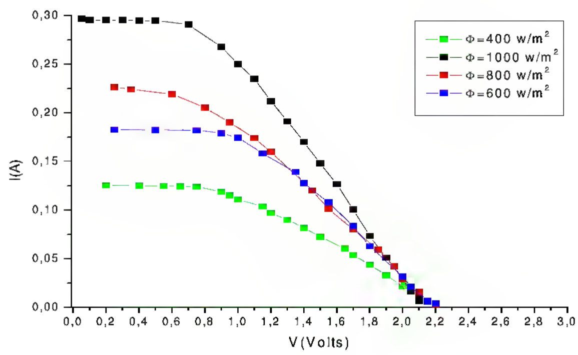

Figure 4: I-V Model Curves and Experimental Data of the Solar Cell at Different Irradiations, 25°C

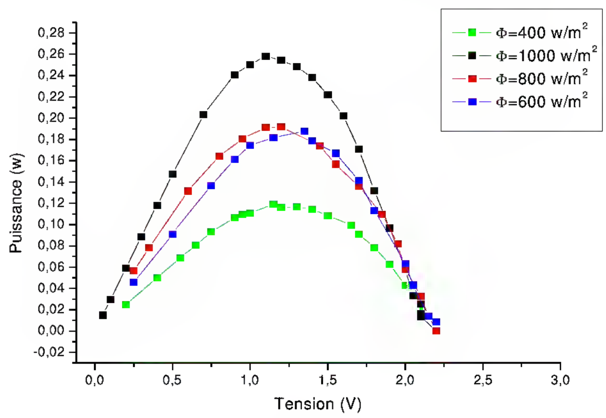

Figure 5: P-V Model Curves and Experimental Data at Different Irradiations

Figures 4 and 5 shows the *I-V* and *P-V* characteristics of PV cell at various solar irradiances. The characteristics describe the output current and power of the PV cell within the functional operating voltage. The amount of the illuminated solar irradiance affects the output current generation. As the solar irradiance increased, PV cell is able to release more electrons thus generating larger current. Hence, the output power is increased as the growing of solar irradiance. The *P-V* characteristic illustrates non-linearity behaviour with appearance of one MPP. The short circuit current Isc and the open circuit voltage Voc was 298 mA and 2.2 V respectively. Also, the MPP is 0.258 W for G=1000w/m^2. While at 400W/m^2 solar irradiance, the MPP is relocated to 2.18 V with the power generation of 0.119W.

EFFECT OF SHADOW ON THE PHOTOVOLTAIC CELL

Solar irradiance, cell temperature, tilt angle shaded condition and the operating condition are among the factors that will influence the output current and power characteristics of the PV module. However, the electricity generation is mainly affected by the level of solar irradiance. The amount of incident light to the PV cell and module will determine the total generation charge carrier hence the generated current in the solar cell [10].

A shadow falling on a cell or group of cells will reduce the total output by two mechanisms:

- By reducing the energy input to the cell, and 2) by increasing energy losses in the shaded cells. Problems become more serious when shaded cells get reverse biased.

To study the influence of the partial shadowing on the solar cell performance, an experiment is performed to investigate that phenomenon under a solar simulation by using a halogen lamp. The experimental work described below was held on a rectangular- shaped of monocrystalline Si solar cell. Shadowing on the solar cell is done using a certain percentage of a completely obscure film fixed on the cell front surface to prevent exposing that part to incident radiation, and the remaining portion of the solar cell was illuminated. Experimental process, firstly shadowing was done for the 1/4 of the surface of the solar cell, we took the values of I and V. After that, we repeated the experiment of shaded for half of surface (sides left or right) for the same cell; then, the 3/4, finally shading of all surface. The I-V curves of a PV-cell are shown in following figure at different levels of shading.

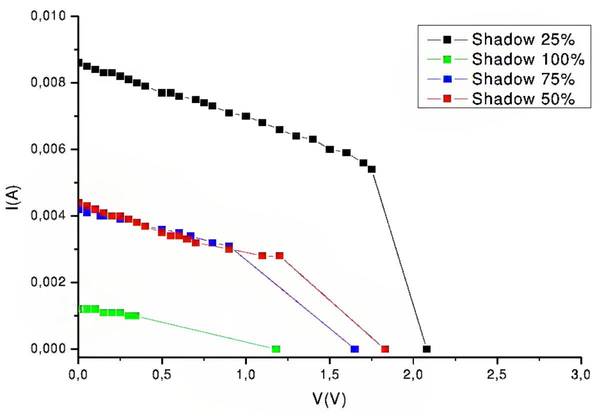

Figure 6: Effect of Partial Shading in I-V Curves

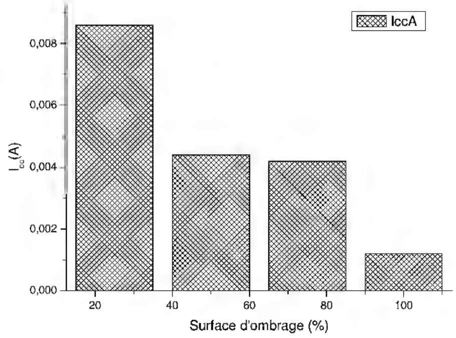

Figure 7: Effect of Shadow on ISC for a Silicon Solar Cell

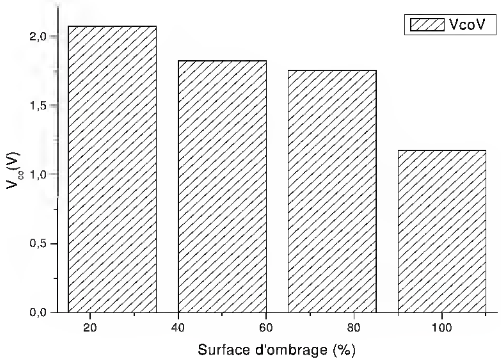

Figure 8: Effect of Shadow on Voc for a Silicon Solar Cell

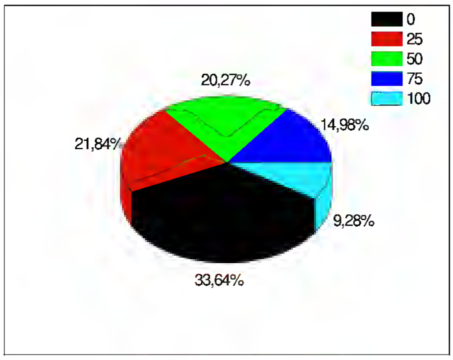

Figure 9: Effect of Different Shading on the Fill Factor

Figure 6 illustrate the characteristics I-V when the PV cell is under shaded condition of 25%, 50%, 75% and 100% respectively. A comparison is done between the cell parameters and performance of the solar cell in case of section by section shadowing, with different shading area relative to the solar cell. All the experimental procedures were done at constant temperature 25°C. It can be observed that the cell which is exposed to 25% partial shading has a MPP=0,0095W compared with the MPP of 75% is 0,0027W.

Figures 7, 8 and 9 show the dependence of the Isc, Voc and the fill factor on the shadowing sector from the solar cell under test. In comparison, a linear decrease of the Isc is observed and the open circuit voltage does not decrease as much until at shadow. However, the short circuit current is much affected by the partial shading of the PV-cell; also the shadowing influenced the fill factor (see figure 9).

The values of the performances parameters of the solar cell were summarized by the table below

Table 1: Performances of Parameters of the Solar Cell at Different Shading

Shaded Surface	0%	25%	50%	75%	100%
Icc (A)	0.298	8.6	4.4	4.2	1.2
Vco(V)	2.2	2.08	1.83	1.76	1.18
Im(A)	0,234	0,0056	0,0028	0,0031	0,001
Vm(V)	1,1	1,7	1,42	0,87	0,32
Pmax(W)	0,5301	0,00952	0,00398	0,0027	0,00032
FF	0,81957	0,5322	0,49379	0,36485	0,22599
η (%)	20,59	0,7616	0,31808	0,21576	0,0256

INFLUENCE OF TEMPERATURE

The temperature is a significant parameter in the behaviour of the photovoltaic cells, would be this only because one cell exposed to a radiance of 1 kw/m² transforms of them into electricity only 12 % at most, the remainder (either 88%) Being dissipated in heat [11].

Table 2 shows the experimental data at three different temperature conditions

Table 2: Parameters of the Solar Cell at a. M1.5, 1000 W/M^2

% Shaded	0%	25%	50%	75%	100%
Icc A (25°c)	331	12,8	4,6	3,7	1,5
Vco V(25°c)	2,5	2,2	1,85	1,75	1,35
Icc A(35°c)	330,9	12	4,3	2,9	1,5
Vco V(35°c)	2,4	2,15	1,85	1,65	1,3
Icc A(50°c)	320	11,9	4,3	2,9	1,5
Vco V(50°c)	2,3	2,05	1,8	1,55	1,2

At a an irradiation of 1000 W/m2 and at three different temperature, the short-circuit current decreases approximately linearly with the area shading. However, the open circuit voltage is affected by the temperature of the PV-cell.At a higher temperature, the open circuit voltage decreases. This is due to an increased probability that an excited electron will collide with an atom in the lattice, as a higher temperature means that the atoms in the lattice vibrate more and therefore have a larger virtual cross-section area.

The phenomenon has quite a large impact and decreases the output power by approximately 15 % at a temperature increase from 25°C to 50°C and at different shading. In this situation we subjected the PV module of Si mono-crystalline for two positions of the sun, but each was subjected to a new level of irradiation. This effect of shadow was carried out on a terrace by one fine day. The results were illustrated by figure (10)

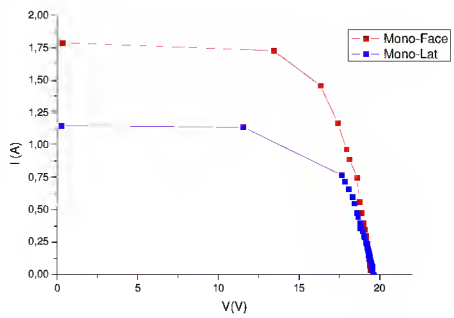

Figure 10: The I-V Curves Experimental of the Module PV to Two Positions

In this first case; the position face the sun we measured the level of irradiation and the temperature of the module on site: G = 540 W/m^2, T=49°c; we obtained the value of the short-circuit current of 1,79A and the opens circuit voltage of 19,56V, there is the MPP of 23,62 W, which is situated at the operating voltage of 14,95Vand Im=1,58A.

In the latter case, we considered the module completely tilted, i.e. a shade partial of the sun with the brightness G = 320 W/m^2, T=42°c, while the other remained in optimal conditions of irradiation. As it can be seen in Figure 10, the current dropped to 1,15A. A Maximum power value was halved in this case compared to the first situation, Pm=13,78W

CONCLUSIONS

In this paper, we have investigated the losses caused by shadow on the surface of cell or module photovoltaic. Then effect of shadowing from the area of solar cell has been tested experimentally by preventing light to reach certain location on the solar cell with the shadow area. However, the characteristic is simple with only the short circuit current in the *I-V* curvature become more important according to the shade. The shading conditions cause the *I-V* characteristic more decrease. This cell PV is trapped at the MPP and reduces the power generation.

The efficiency of the photovoltaic is very important especially nowadays where all the world is seeking for the renewal energy.

In my future work, the behaviour of a solar cell/module under shadowing effect could be explained by the two diode model, a comparison between the experimental study and the theoretical results i.e. a computer simulation for the process will be studied.

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